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Using the History of Science as a Tool for Teaching: Strengths and Weaknesses of Pre-service Biology Teachers

Bilim Tarihini Bir Öğretim Aracı Olarak Kullanmak: Öğretmen Adaylarının Güçlü ve Zayıf Yönleri

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USING THE HISTORY OF SCIENCE AS A TOOL FOR TEACHING: STRENGTHS AND WEAKNESSES OF PRE-SERVICE BIOLOGY TEACHERS

ABSTRACT

The history of science (HOS) is considered a potential resource and a meaningful device for not only learning the content but also developing an understanding of the nature of science. The purpose of this study is to observe the experiences of pre-service teachers during their teaching practices based on HOS to understand their positions in instruction. A qualitative methodology was utilized with the participation of 15 pre-service biology teachers who enrolled in a using HOS in biology teaching course. At the end of the semester, pre-service teachers were asked to prepare a lesson plan and enact a lesson based on HOS covering the subject that they selected before. Data were collected through lesson plans and reflective journals. Inductive code generation and collective comparison were employed for the analysis. Analysis was presented under three themes as before, during, aspeand after the teaching practices and revealed preservice teachers' purposes, concerns, strengths, weaknesses, and decisions during the whole process. The results of the research revealed that while pre-service teachers stated that HOS was easy to use for humanization, they had difficulty in making a connection between HOS and content knowledge. These findings can help design teacher education programs with courses of the HOS, which focuses on pedagogical aspects as well as conceptual aspects.

Keywords: Classroom Practices, History of Science, Teaching, Pre-service Teachers.

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BİLİM TARİHİNİ BİR ÖĞRETİM ARACI OLARAK KULLANMAK: ÖĞRETMEN ADAYLARININ GÜÇLÜ VE ZAYIF YÖNLERİ

ÖZ

Bilim tarihi (BT), alan bilgisinin yanı sıra bilim doğası hakkında anlayış geliştirmede potansiyel bir kaynak ve anlamlı bir eğitim aracı olarak kabul edilmektedir. Bu çalışmanın amacı, öğretmen adaylarının BT'ye dayalı öğretim uygulama deneyimlerini gözlemlemektir. Bilim tarihi ve felsefesi dersini almakta olan 15 öğretmen adayı ile yürütülen bu nitel araştırmada, adayların kendilerinin belirlemiş olduğu konulara ilişkin BT ile bütünleştirilmiş ders planları ve bu plana dayalı bir ders işleyiş süreçlerine ilişkin yansıtıcı günlükleri analiz edilmiştir. Analiz için tümevarımsal kod oluşturma ve kolektif karşılaştırma yöntemleri kullanılmıştır. Elde edilen kodlar, öğretim uygulamalarının öncesi, sırası ve sonrası olmak üzere üç tema altında sunulmuş ve öğretmen adaylarının bilim tarihi ile bütünleşik bir ders tasarlanmasına ilişkin amaçları, endişeleri ve bu konudaki güçlü ve zayıf yönleri süreç boyunca ortaya çıkarılmıştır. Araştırmanın sonuçları, öğretmen adaylarının BT'nin insanileştirme açısından kullanımı konusunda kendilerini rahat hissettiklerini ancak BT bilgisi ile alan bilgisi arasında bağlantı kurmakta zorlandıklarını göstermiştir.

Anahtar Sözcükler: Bilim Tarihi, Öğretmen Adayları, Öğretim, Sınıf Uygulaması.

INTRODUCTION

History of Science (HOS) is fundamental to all sciences. Whether it is natural sciences or social sciences, knowing the HOS in which science is studied, and knowing the development process of science can allow one to take the right steps for the development of that discipline (Matthews, 1994). HOS is not just a chronological source. It also reveals the scientific, sociocultural, sociological, political, and philosophical structures in which concepts are developed. It also provides information on the development of science, the conceptual development of scientific concepts, and the sociocultural effects of these developments. For this reason, university curricula for almost all sciences involve the HOS as a course. It is valid for teacher education programs (TEP). The HOS for natural sciences has credit in teacher education curricula. Science teachers have the responsibility to present science to students in historical, philosophical, and cultural frames (Abd-El-Khalick and Lederman, 2000; Matthews, 1994). Since NOS has become an important component of science education to achieve the goal of science literacy, many studies have covered how to include science in the classroom. In this context, the HOS is a potential resource to enhance understanding of many tenets of the NOS as well as scientific content (Abd-El-Khalick and Lederman, 2000; de Hosson & Decamp, 2014; Guney & Seker, 2012; Irwin, 2000). Many studies showed that using the history of science as an educational tool contributes to the teaching process from different perspectives such as developing conceptual, epistemological, or interest in science (Adúriz-Bravo & Izquierdo-Aymerich, 2009; Clough, 2006; Henke et al., 2009; Piliouras et al., 2011; Bakanay and Cakır, 2022; Seker, 2012). At best, teachers remain at the level of using the HOS only for conceptual purposes or as an additional source of information (King, 1991; Wang and Cox-Petersen 2002; Bakanay and Guney, 2018).

Bakanay and Çakır (2022) pointed out that if science teachers lack sufficient awareness of how and why the integration of the HOS is important in science education, it can be interpreted that the HOS is just another source of information. Teachers need to develop perspectives and pedagogical tools to introduce this kind of knowledge and make it relevant to school science in the classroom (Monk and Osborne 1997; Galili and Hazan 2001). There is a pressing need to investigate the readiness of science teachers' approaches to science teaching through the history of science (Wang and Cox-Petersen 2002). From this point of view, the nature of the HOS course should be different.

The current study focuses on how teacher education programs can help pre-service teachers in their use of HOS and how courses in TEP can be developed for the effective use of HOS in science lessons. Concerning the focal point of the study, the aim is to suggest ways to improve the content of HOS courses in teacher education programs. The context of the current study emphasizes explicitly the historical and cultural contexts of science and mentions the philosophy of science implicitly since the national science curricula in Turkey do not emphasize the philosophy of science explicitly. To that aim, the study observes preservice teacher's experiences with their use of the HOS in their lessons.

The current study is based on the literature on HOS in science education, the place of HOS in Turkish curriculum, the use of the history of science in instruction, and the role of HOS in teacher education programs. Therefore, concerning brief is summarized in the following sections.

The History of Science in Science Education

The HOS in science education is emphasized in present-day education. Research on the use of the HOS in science education has results including learning the content of science, understanding methods of science, developing problem-solving skills and alternative concepts of students, understanding of nature of science, science and society interaction and interest, attitudes, and motivation on science (Seroglou and Koumaras, 2001). It is recognized that the use of the HOS in science education helps in understanding how scientific ideas were developed (NRC, 2012), and how different cultures affected science (NAEP, 2007); understanding social and intellectual aspects of science, tentative nature of science, and methods of science, humanizing science, and promoting reasoning (Leite, 2002). Research showed that the HOS has positive effects on learning concepts (e.g. Klopfer and Cooley 1963), understanding the nature of science (e.g. Solomon, Duveen, and Scot, 1992), student's interest in science lessons (e.g. Becker, 2001), and attitudes toward science (e.g. Lin, 1998). Therefore, these fruitful outcomes made national curricula emphasize and verbalize the role of the HOS in science education. Before considering the Turkish curriculum on which this study is based, considering the leading curricula in education will help to grasp the place of the history of science in science education, as it follows the parallel mission and vision. The motto of science for all by the American Association for Advancement of Science can be underlined as the most important step concerning the use of the HOS in science education.

The teaching of science must explore the interplay between science and the intellectual and cultural traditions in which it is firmly embedded. Science has a history that can demonstrate the relationship between science and the wider world of ideas and can illuminate contemporary issues (AAAS, 1990, p. xiv). In Project 2061 conducted by the American Association for the Advancement of Science (AAAS), Benchmarks for Science Literacy consists of 12 parts (criteria) including the HOS (Chapter 10. Historical Perspectives). AAAS (2009) states that the HOS is a good way to understand how science works, and historical case studies, biographies, and other source studies will be important resources to gain an understanding of the nature of science. AAAS emphasizes the use of the HOS in different departments for 9-12 grade levels. In addition, U.S. Science Education Standards published by the National Research Council underline and suggest the use of HOS in school science programs.

> *The standards for the history and nature of science recommend the use of history in school science programs to clarify different aspects of scientific inquiry, the human aspects of science, and the role that science has played in the development of various cultures (NRC, 1996, p.107).*

On the same basis, A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (2012) addresses the role of the history of science in understanding how scientists work and how scientific ideas progress in social, cultural, and scientific contexts.

> *The idea of science as a set of practices has emerged from the work of historians, philosophers, psychologists, and sociologists over the past 60 years. This work illuminates how science is actually done, both in the short term (e.g., studies of activity in a particular laboratory or program) and historically (studies of laboratory notebooks, published texts, eyewitness accounts) (p.43).*

> *Historical case studies of the origin and development of a scientific idea show how a new idea is often difficult to accept and has to be argued for (p.71)*

> *Students … should also recognize that much of science deals with constructing historical explanations of how things evolved to be the way they are today, which involves modeling rates of change and conditions under which the system is stable or changes gradually, as well as explanations of any sudden change. (p.101)*

British Association for the Advancement of Science suggests a focus on HOS since the middle of the 20th century (Jenkins, 2007).

History and biography enable a comprehensive view of science to be constructed, which cannot be obtained by laboratory work. They supply a solvent of that artificial barrier between literary studies and science that a school timetable usually sets up (British Association 1918).

English National Curriculum - addresses the use of HOS in science instruction as well:

Pupils should develop their knowledge and understanding of the ways in which scientific ideas change through time and how the nature of these ideas and the uses to which they are put are affected by the social, moral, spiritual, and cultural contexts in which they are developed (NCC, 1988, p. 113).

The National Curriculum in England (2014) for science -key stages three and four aims at understanding how science works and promotes the use of the history of science in instruction:

'Working scientifically' is described separately at the beginning of the program of study, but must always be taught through and clearly related to substantive science content in the program of study. Teachers should feel free to choose examples that serve a variety of purposes, from showing how scientific ideas have developed historically to reflecting modern developments in science. (DfE, 2014, p.70)

Brazilian studies are noteworthy in the use of HOS in science education. Since science education standards include the history and the nature of science, Brazil is nominated as the future leader of science education (Allchin, 2008). A collective study under the edition of Silva and Moura (2019) which is on humanistic objectives, and scientific content through contributions from the history and philosophy of science in science teaching can be shown as an example of the Brazilian perspective on HOS. Therefore, as a reflection, a curricular guideline for Secondary Education addresses the use of HOS.

(a) To understand the sciences as human constructs, recognizing that they develop by accumulation, continuity, or paradigm rupture, correlating the scientific development to the transformation of society; […] (i) To understand the relation between the development of the natural sciences and the technological development and to associate the different technologies to the problems that they intended to solve; (j) To understand the impact of the technologies associated to the natural sciences in the student's personal life, in the production processes, in the development of knowledge and in social life. (Brazil, 1998 in Martins, Silva and Prestes, 2014).

A recent publication, Pathways for Natural Science in the Brazilian National Common Curriculum (2020) details the role of integrating the history of science in instruction in chapter 9 called "The history of science in the classroom: studies of historical cases."

> *Including narratives from the history of science in an investigative way in the classroom can be a powerful strategy for developing an understanding of aspects of scientific practices and the nature of scientific knowledge. A historical trajectory to guide students in research and problem solving through research that drives their research and proposed research. … Working through investigative case histories enables students to develop skills that allow them to evaluate claims and evidence of contemporary scientific issues in science under construction. (BNNC, 2020 p. 136)*

The History of Science in the Turkish Curriculum

As can be seen, many countries that are education leaders have made the history of science a part of science education in their curricula and have presented the reasons for this in their programs. Like many governments around the world, the Turkish government is aware of the importance of preparing its citizens for the challenges of the new century, and has introduced many reforms at various levels of education in the last decade. With this movement, teaching and learning the nature of science has become the prime target of the new secondary biology curriculum in 2007 (Irez and Çakır, 2010). The new curriculum urges biology teachers to bring up important aspects of science in the classroom (e.g. the role of indirect evidence and inference in science) and introduce students to the key concepts and perspectives of contemporary philosophy of science (such as Kuhnian paradigms and paradigm shift). At this point, the history of science has started to take place in the curriculum objectives since 2007. After 2007, The Turkish science curriculums were revised twice in 2013 and 2018. The place of the history of science in the curriculum has not changed and has preserved its place in each renewal version. Some of the examples are;

In 2007 (MEB a, 2007);

> *The program emphasizes the history of science, and the culture of science, and the interactions of science with society and the environment (p. 16).*
>
> *Evaluate the studies on the cell in the historical process (p.31).*
>
> *Explain with examples the contributions of human societies with different historical and cultural backgrounds to the development of scientific ideas of biology. (p.17)*

In 2013 (MEB b, 2013);

To ensure the continuity of teaching the nature of scientific knowledge, activities such as examining the history of science and examining historical scientific studies were supported. (Curriculum Objectives, p. III)

"Examples of scientists who have contributed to cell-related information in the historical process (Robert Hooke, Antonie van Leeuwenhoek, Matthias Schleiden, Theodor Schwann, and Rudolf Virchow) are given (9th grade, Unit of Structure of cell, p.3)

The development of concepts, models, and theories related to heredity in the history of science is examined (10th grade, Unit of Heredity, p: 9).

The dynamic structure of scientific knowledge is discussed through the historical development of knowledge about photosynthesis (12th grade, Unit of Photosynthesis, p.30).

In 2018 (MEB c, 2018)

Recognizes some scientists who contributed to the field of biology in the history of science. (Curriculum Objectives, p.11)

Avicenna's studies on human physiology are examined. (11th grade, Unit of nervous system, p: 23)

Ian Wilmut's cloning studies are mentioned (12th grade, Unit of Heredity, p: 30)

In Turkey, textbooks are prepared with the curriculum criteria determined by the Ministry of National Education. After each revision in the curriculum, the Turkish biology textbooks are updated and delivered to schools free of charge to use in the new academic year. Many science teachers, new teachers in particular, view textbooks as a reflection of the curriculum and outline their lessons in the order of progression of concepts in the textbook (Chiappetta et al., 1993). Considering this acknowledgment, some national studies have examined the history of science stories in textbooks. Those studies concluded that there was a lack of emphasis on contextual and simple focus on conceptual and procedural understanding in Turkish biology textbooks (Sarıbas, 2019; Yıldız, 2013).

Although studies underline the potential benefits, curricula emphasize the place and curricular objectives address the use of HOS in science instructions, it would not be sufficient to agree with the idea that teachers can easily enact a curriculum based on HOS (e.g. Seker and Guney, 2012). Studies have indicated that teachers are often ineffective in integrating HOS into their classroom practices (King, 1991; Wang, 1999).

The Use of the History of Science and Teachers in Action

Teachers are not knowledge transmitters. They are an active part of the instruction who should shape their instruction considering unexpected and sometimes unforeseen reactions from the students (Remillard, 2005). They continuously make decisions during class time. Duschl (1987) defines the decisions of teachers as pre-active and interactive decisions; pre-active decisions are selecting and organizing materials to be used in instruction and interactive decisions are decisions made while interacting with students. He underlines the issues that teachers experience regarding these decisions. Teachers should design and deliver instruction as both pre-active and interactive effective decisions (Duschl, 1987). The place of the concept of decision-making in the teaching process has been discussed in many studies (e.g. Hunter, 1979; Shavelson, 1973; Borko et. al. 1979; Borko et. al. 2008; Clough et. al., 2008). It is known that the teacher's knowledge, beliefs, experiences, the subject discussed, interaction with the student, and many factors play a role in the decision-making process. Clough et. al. (2008) states that the teacher's decisions reflect feedback on many subjects such as content, tasks, materials, models, and strategies, thus creating the learning environment. These decisions underscore why a lesson is going well or not and provide a basis for understanding how problems can be resolved. The decision-making framework they created in this direction provides a framework for the content to be taught, the tasks and activities to be applied, the materials to be used, the teaching models and strategies to be discussed, and the behaviors and interactions to be exhibited. Clough et. al. (2008) also highlights the importance of addressing this framework in teacher education for teachers' professional development.

This study is based on the acceptance that teaching is a decision-making process and supports the idea of using the decision-making framework emphasized by Clough in teacher education. However, the factors affecting decision-making or the application of the decision-making framework are beyond the scope of this study. In light of the scope of this study, it is shown that there are difficulties affecting the decision-making processes of teachers regarding the application of the history of science, and that these difficulties are both the structure of the history of science, and the use of the history of science in science lessons. These difficulties may cause teachers to experience challenges in decision-making processes and to be unable to provide the course flow in the process of using the history of science in science lessons.

However, having difficulties concerning the use of HOS can make teachers falter in their interactive decisions during instruction. A study that discusses the difficulties in preparing instructional materials based on HOS aligned to the curriculum reported the following obstacles (Seker and Guney, 2012):

- Limited information about the lives of (some) scientists
- Link with the content knowledge
- Lack of information related to content knowledge
- Lack of information about scientists' reasoning
- Variety of scientific methods
- Difference between historical chronology and curricula
- Interdisciplinary nature of concepts which is not detailed in curricula
- Simplifying complex information (e.g. philosophical information on concepts)
- Different (historical) terms or phrases

Even the phase of developing instructional materials based on HOS requires detailed preparation. Therefore, it is expected that a teacher would face challenges in using unfiltered HOS information in their lessons. Considering the use of HOS in science instruction, research showed that teachers have problems in adding historical content into the curricula, considering historical standards with contemporary views, and filtering historical information for the lesson (Leite, 2002). Providing materials filtered with the aims of the instruction may be insufficient. For instance, in a study that used curriculum-aligned HOS-based instructional materials, teachers underlined that historical information that covers philosophical content, complex experiment designs, and scientists' scientific approaches were too complex for teachers to understand and enact in the classroom since they cannot link the information with content knowledge and sometimes cannot decide how to enact (Bakanay and Çakır, 2022). Therefore, teachers' preservice education should cover credits to facilitate the use of HOS in science lessons.

The History of Science in Teacher Education Programs

Researchers have been underlining the need for history and philosophy of science in teacher education programs since the 1980s. Duschl (1987) advocates the use of HOS and insists that without armed with philosophical, historical, and sociological aspects of science training would be insufficient for teachers. Although teacher education programs concentrate on core courses and pedagogical courses, Duschl insists that without being armed with philosophical, historical, and sociological aspects of science, the given training would be insufficient for teachers.

Mathews (1997) underlines the HOS in teacher education since teachers should have more knowledge about the content than they ought to teach and they are responsible for presenting science in historical, philosophical, and cultural frames. The course designed by Matthews (1991 in Matthews, 1997) covered two episodes 17th-century physics and 19th-century biology with the writings of milestone scientists of the concepts, and focused on philosophical issues behind the texts which facilitated it for teachers to discuss and interrelate science with various contexts (e.g. intellectual, economic, religious, ideological).

Moura and Silva (2018) suggest that teacher education should have HOS to encourge teachers to criticize and transform education. Incorporating HOS in teaching, which involves mediating interactions among humans, perceiving science within the frame of its cultural context, and providing an environment for students to engage in science, may facilitate being critical and transformative teachers. According to Moura and Silva (2013), presenting knowledge on HOS (or HOS) is not solely sufficient since a revision for teacher training should be thought to nest HOS with the content. Thus, they proposed a Multicultural approach of the history of science for teacher training in which the scientific context covers both theoretical and practical dimensions; the meta-scientific context, which focuses on the aspects of the nature of science explicitly; and the pedagogical context, which covers future teachers' experiences and reflections on their use of the HOS in their teaching practices.

Likewise, Heering (2009) considers the possible fruitful effects of the HOS in science education such as understanding the scientific concepts and the aspects of NOS, and developing scientific literacy. Therefore, in his study he supports the implementation of historical experiments in teacher education to understanding scientific methods and error-sensitive nature of scientific studies, developing conceptual understanding, and perceiving the cultural context of science. Teacher education requires a HOS course that is apt to their professional needs. Therefore, the current study emphasized preservice teachers' professional needs such as having historical information based on the context of the curriculum and the pedagogical approaches to use HOS in instruction. The perspective of the current study is detailed in the following sections.

History and Philosophy of Science in Biology Teacher Training Program in Turkey

In Turkey, higher education undergraduate programs are established by the Council of Higher Education (Turkish: Yükseköğretim Kurulu, YÖK), a central regulatory body of the government. YÖK was established in accordance with Law No. 2547 on Higher Education in 1981. The relevant institution is responsible for preparing and conducting inspections, on behalf of the YÖK, to ensure compliance with the purpose and main principles specified in the relevant law in terms of education, teaching, and other activities at higher education institutions. When examining the biology teacher training program published by YÖK in 2018, it is seen that there are courses related to the history and philosophy of science within the scope of both field-specific and general culture courses.

When the contents of the elective courses in the field, such as the philosophy of science and biology literacy, determined by YÖK (Higher Education Council), are examined, the following explanations are seen:

In The Course of Biological and Scientific Literacy;

> *"The fundamental characteristics of science and scientific knowledge; characteristics of a science-literate individual; the significance of biology science and its place among other disciplines; fundamental concepts, principles, theories, and their relationships within biology science; scientific practices and process skills; the nature and philosophy of biology science; the historical development of biological concepts (cell, genetics, classification, systems, evolution, etc.) and the methods used by scientists who played a role in this development; the interaction between biology, technology, society, culture, and the environment; genetic literacy; biological technologies, the impact of current biological applications on society and the environment; personal decision-making process, bioethics, attitudes, and values; environmental and societal values; career planning, lesson plans, project development and presentation, drama". (page 25)*

In the course of Philosophy of Science and Nature of Science:

> *"The description of the philosophy of science, its purpose, subject, philosophical movements, paradigms, debates, and its impact on the development of science; the definition of science, its objectives, characteristics, development, and stages it has gone through (with a focus on biology science); the history of discoveries; epistemology, ontology; the nature of scientific concepts, how knowledge is acquired, and the characteristics of scientific knowledge; the concept of existence; scientific thinking, scientific inquiry; science and society, the sociology and anthropology of science; scientific ethics; the interaction of science with society, technology, and the environment; scientists and their characteristics, misconceptions related to these topics" (page 24).*

It is possible to say that both courses have comprehensive content regarding the development and change of science, especially in the context of biology. However, the fact that these courses are offered as electives in the program is a point that can be subject to discussion. In addition to these, under the general culture elective course category, a separate course on the history and philosophy of science is also available. The in the course of history and philosophy of science;

"Science, philosophy, scientific method; science and philosophy in Ancient Greece, Medieval Europe, Scholastic philosophy and science; science and philosophy in the Islamic cultural geography; science in Mesopotamia; science and philosophy in Renaissance Europe; science and philosophy in the Enlightenment era; classification of sciences; science, scientism, ideology, ethics, and religion relationships; science and paradigms; Vienna and Frankfurt Schools of thought; critiques of science in the twentieth and twenty-first centuries" (page 20).

In addition, there is a separate course on the history and philosophy of science under the general culture elective course category. However, since this course is open to all departments at the university, it does not include field-specific practices and includes chronological and periodic information about the history of science. It is not possible to say that there is a standardized program for pre-service biology teachers because the relevant courses are elective.

Aim of the Study

In this study, it is argued that if teachers do not feel confident about their decisions to use HOS in their teaching practice, they will not use it in their lessons. Considering the potential outcomes of using HOS in lessons and the objectives of the curricula, teachers need to engage HOS in their teaching practices. Hence, teachers should be armed with the content knowledge and the pedagogy on HOS to be effective decision-makers. Therefore, the study aims to suggest ways to improve the content of HOS courses in teacher education programs by observing preservice teachers' experiences during their use of the HOS in their teaching practices. The current study addresses the following questions

- What do preservice teachers think of using HOS before, during, and after the teaching practice?
- What are the purposes of preservice teachers in using HOS?
- What affects the experiences of preservice teachers on the use of HOS in teaching practice?
- What are the obstacles that preservice teachers encounter during the teaching practice?
- What are the strengths of the preservice teachers in using HOS?

METHOD

The current study focuses on pre-service teachers' feelings and thoughts about their practical experience. It aims to analyze how the process during their teaching practices works, what they need to use the HOS as a teaching tool, and where they find themselves sufficient or insufficient rather than stating the point they reached at the end of the process. Thus, an interpretive paradigm was employed for this study to understand what people experience through interpreting cases. The case study research design allows the author a deeper understanding of the pre-service teachers' feelings, needs, and challenges through their teaching practices.

Case studies provide a holistic means of describing and interpreting phenomena, which are bounded and integrated with the context (Merriam, 1998). Therefore, the author systematically looks at what is happening between context and phenomenon (Bromley, 1990). In this study, the pedagogical-based HOS teaching practice experiences of pre-service biology teachers are the case under scrutiny

Characteristics of Case Study in This Research / Context

The study was conducted in the history of science course that is offered by biology teacher education programs in a public university in Turkey. This course is in the last semester of senior year of the education program, and lasts for ten weeks. Each lesson is given for two and a half hours in a week meeting in a classroom. The author developed the HOS course program considering the theoretical information on the use of the HOS in science lessons and the related pedagogical methods. The course included various teaching methods and techniques such as creative writing, narrative, historical experiments, using some artworks, etc. for using HOS in science education rather than chronological information about the HOS. Table 1 shows the details of the course as a syllabus.

The role of HOS in science education and ways to integrate HOS in instruction underlie the basis of the course. In the first two weeks of the course, the author revised the historical background of using HOS in science education, and the milestone projects on the HOS. Curriculum and HOS interaction was analyzed within the frame of the current national biology curriculum and discussed to understand the role of HOS in science education. In the third week, pre-service teachers were to select a subject from the curriculum. These subjects were the concepts that they would enact in the classroom at the end of the semester. For the rest of the semester, the researcher presented the ways of using HOS in science education and exemplifying materials. Looking at the overall structure of the course, it is aimed to address the conceptual, epistemological, sociocultural, and interest levels of the model (Seker, 2012) of using the history of science in science courses. For example, for a lesson based on conceptual aims, the use of binary opposites (how phenomena were explained by opposite ideas) was explained and the argumentation method was reviewed and exemplified. In addition, instructional materials based on the HOS and coherent with the national curriculum were presented during the classes.

Table 1. *The Syllabus for the HOS course designed for the study*

Lesson	Content	Activity	Task
1	Presenting the content and scope of the course		….
2	What is the history of science? Dimensions of HOS in education.	Dimensions of HOS in education (Conceptual, Epistemological, Socio-cultural and Interest Level)	Curriculum review Defining objectives concerning HOS
3	HOS in curriculum and scientific literacy	History of HOS in science education Choose topics to study	…..
4	HOS as a teaching method	Documentaries as an educational teaching method BBC “The Story of Science- How we get here?”	Finding documentaries or films concerning scientific concepts
5	HOS and creative writing	“Charles du Fay- Explorative Experiments” Interaction between scientific theories and laws	Classroom activity
6	HOS and artworks	Discussing artworks concerning scientific developments used in education Science and society interaction	Finding examples and presentations in class
7	Women in the history of biology	Discussing the role and process of the existence of women in science. Example of today’s women scientist	Essay about science and society relation specific to the image of a scientist
8	HOS and scientific method	Authentic science and historical experiments	Finding historical questions and hands-on science
9	Paradigm and structure of scientific revolutions	What is Paradigm? Examples from biology, physics, and chemistry. Binary opposites and alternative concepts	What is the current paradigm in biology? What was the previous paradigm?
10	A trip to Science and Technology museum	Istanbul Museum of the History of Science and Technology in Islam	…

At the end of the semester, pre-service teachers were asked to prepare a lesson plan and enact a lesson based on HOS covering the subject, which they selected before. Pre-service teachers have remained stay loyal to the curriculum when preparing lesson plans integrated with the history of science. They adapted the lesson plan in the biology curriculum of the Ministry of National Education to include the history of science. Depending on the level of the class they will be teaching, they have selected unit topics from the curriculum that align with the subject and semester flow, taking into consideration the relevant curriculum objectives. For this reason, PSTs' have developed various plans for different grade levels. For example, P3 has selected the achievement numbered 12.1.2.2 from the twelfth-grade curriculum, which involves evaluating the impact of genetic engineering and biotechnology applications on human life. In his lesson plan, s/he has also addressed that s/he will relate his/her lesson plan to the specific objectives of the biology program, including "1. Knowing the laws, theories, processes, principles, hypotheses, and experiments in biology," and "11. Aimed at individuals who are inquiring, critical thinkers, collaborative, possess effective communication skills, problem solvers, inquisitive, productive, and willing to learn about science throughout their lives." (M.E.B; 2018; p. 11). (See below Table 3).

The design and the scope of the plan were left to the participants. The author did not intend to control the participants or their teaching experience. During the process, pre-service teachers were not directed but they gave feedback when they asked to. After designing the HOS plans, teacher candidates carried out their activities in at least one of the practice lessons in a real classroom environment. The real classroom environment provided by the Teaching Practice course in which pre-service teachers are already enrolled for the semester.

Participants

A total of 15 pre-service biology teachers (10 women and 5 men) who were enrolled in a using HOS in biology teaching course participated in this study. Participants studied at a department of biology education in a public university in Turkey. Only three pre-service teachers (T3, T6, and T11) worked in a private study center as biology teachers to assist high school students in their university preparation processes. Except for these three participants, none of the participants had any teaching experience.

Although the pre-service teachers had the opportunity to teach in a real classroom environment within the scope of the education they received in the last year of the university, except for the three pre-service teachers mentioned, the candidates did not have professional teaching experience. The HOS course, in which the application was carried out, is a course they take in the last year of teaching. During their education, students completed field and pedagogy-based teaching courses for biology education. All of the participants were taking the relevant course for the first time. For a full academic year, pre-service teachers took a course that was focused on the theoretical information on the use of the HOS in science lessons and the related pedagogical methods

Data Collection Tools

Data were collected through lesson plans and reflective journals, from 15 pre-service teachers. Reflective Journals are an analysis tool that helps pre-service teachers to think about the problems they face and to reveal their feelings and thoughts about the process as well as helping them to make teaching plans. Throughout the implementation process, each pre-service teacher shared their teaching experiences through reflective journals. Reflective journals were designed according to the Campbell-Evans and Maloney's, (1998) framework that consisted of four levels (describing, informing, confronting, and reconstructing) of reflection. These journals consist of three sections that cover pre-implementation, implementation, and post-implementation experiences.

The participants talked about their feelings and thoughts about how they intended to progress the lesson in the first part. In this section, participants were asked to write their action plans for the process. In the second part, participants described their experiences in the class. It was the part where they shared their feelings and thoughts during the process, such as if any changes caused them to get out of their plans. In the last part, pre-service teachers wrote their views on how they would do if they did this practice again at the end of all experiences. The pre-service teachers filled out the journals after each HOS experience and sent them to the researchers

Data Analysis

Inductive code generation and collective comparison were employed for the data analysis. The analysis process was carried out with two different researchers independently.

After the coding process, researchers compared and contrasted their findings. Generated codes were grouped under sub-themes and themes. Details concerning coding schema are presented in Table 2.

Table 2. *Codes and sub-codes as a result of data analysis*

Theme	*Sub-themes*	*Codes*
Before	Purposes	Humanize science and scientist Teaching scientific concept Reinforce learning The tentative NOS Teach science & society interaction Attract student attention to the topic Enhance teaching
	Concerns	Expectation of students Lack of experience
During	Decisions Student engagement	Time management Interaction
After	Strengths	Professional pleasure Professional development Effective lesson
	Weaknesses	Lack of information Time management Lack of pedagogy Linking information (HOS and content knowledge) External factors

Ethics Committee Approval

Ethics committee approval was received for this study from Istanbul Aydin University, Faculty of Education

The Title of The Ethics Committee: Ethics Committee for Educational Sciences Ethics Committee at Istanbul Aydin University

Approval Date: 02.03.2023

Ethics Document's Number: 79916

Validity and Reliability

Within qualitative paradigms, the fundamental criteria for assessing quality are often defined as Credibility, Confirmability, Consistency, and Transferability (Lincoln and Guba, 1985). To ensure the credibility of this research, which was designed as a case study, data triangulation was employed. Long-term interactions were established with prospective teachers through the lesson plans they prepared and the reflective journals they filled out throughout the process, and the data were examined from a comprehensive perspective. Lincoln and Guba (1985) state that providing a detailed description of the data obtained from participants enhances the transferability of qualitative research. In this study, detailed quotations from the participants, as well as a detailed introduction of the context and conditions in which the process and phenomenon occurred, increased transferability. Throughout the research, expert approval was obtained by utilizing expert opinions in the coding and interpretation of the data, in addition to the researchers' efforts. During the process, the researcher shared the judgments reached as a result of the analysis with the pre-service teachers and obtained their confirmation, taking participant control by receiving explanations about the extent to which the relevant views reflected their own experiences (Curtin and Fossey, 2007).

FINDINGS

The purpose of the current study is to present a detailed case study on preservice teachers' experiences with using the HOS in their instruction. This study investigated the experiences of preservice teachers. The findings are presented in three themes: before the teaching practice, during the teaching practice, and after the teaching practice. Experiences before the teaching practice phase cover preservice teachers' plans and intentions for utilizing HOS; experiences during the teaching practice phase cover their reactions concerning in-class actions, and experiences after the teaching practice phase cover their self-evaluations.

Experiences Before Teaching Practice

In the process, pre-service teachers' plans for their experiences before using the HOS and their concerns (if any) were examined by analyzing the first part of the pre-service teachers' lesson plans and reflective journals (Theme 1). In the lesson plans they prepared, how much they included the HOS, at what stage of the course, and for what purpose they planned to use it were examined.

Purposes

Findings from lesson plans.

Based on preservice teachers' lesson plans, it is noteworthy that the majority of the preservice teachers planned to add the HOS to their lessons with an add-on approach (11/15) and 5 preservice teachers considered the HOS in an integrated approach. Pre-service teachers who demonstrated the add-on approach use the HOS as an extra-curricular resource to strengthen conceptual learning, draw attention to the lesson, or reinforce what has been taught. It was seen that those who included the HOS during the first 10 minutes of the course started the lesson using historical information and then stated that they would continue the main subject with a traditional narrative flow. For example, in the 0-7 minutes of T1's lesson plan, there was a question-answer activity about the history of heredity to examine the prior knowledge of the students. In the following 20-minute period, it was seen that the purpose was stated as "giving prerequisite concepts to prevent misconceptions that may occur during the lesson" and the process of teaching the information in the textbook was started with the slides. Between 20-25 minutes, it was seen that T1 included the HOS again and added to his plan by mentioning the life of Francis Collins and showing that he was a common person. Similarly, it was seen that T10 used the HOS by adding interesting questions from the history of heredity in the lesson plan to attract attention to the lesson. The statement "Spe-emann's work for cloning is drawn on the board, and then the lecture is given th-rough this drawing," in her lesson plan shows that T11 likewise included the HOS in her lesson plan after the 15th minute. It was seen that the pre-service teachers who added the HOS to the last 10 minutes of their lesson, benefited from the HOS to ask reinforcing questions after the lecture. The HOS was spread throughout the course in the lesson plans of the teacher candidates who demonstrated the integ-rated approach. (5/15).

Table 3. *Participants and their topics*

Partici-pants	Unite	Chosen Topic	Related Curriculum Object
P1	Classical Genetics	History of genetics	10.2.1.1. a and b
P2	Living Things	History of classification	9.3.1.1.
P3	Modern Genetics	Biotechnology and genetics	12.1.2.2
P4	Living Things	History of classification of Linnaeus	9.3.1.2 b
P5	Circulating System	The structure and function of the blood	11.1.4.1 a
P6	Circulating System	The history of human blood groups	11.1.4.1 d
P7	Structure Of Cell	Discovery of cell and cell theory	9.1.1.1
P8	Living Things	History of classification- binomial system	9.3.1.2 c
P9	Living Things	History of classification- modeling-	9.3.1.1 a
P10	Modern Genetics	History of cloning research	12.1.2.4 c
P11	Living Things	History of classification (Aristotle and Linnaeus)	9.3.1.1 a
P12	Modern Genetics	History of DNA model	12.1.1.1
P13	Circulating System	The history of circulation and structure of the heart	11.1.4.1 c
P14	Molecular Genetics	History of cloning research	12.1.2.4 b
P15	Living Things	Discovery of bacteria	9.3.2.1 a

For example, it was seen that P4's lesson was planned as a lesson progressing in the historical process. In the plan, students were asked to depict a hyacinth, compare it with another flower, indicate their differences, and give a name to the relevant flower. Then, it was seen that it was planned to make comparisons with the historical drawing Linnaeus made for the same type of flower. Another lesson plan that could be given as an example is P5. It was seen that the scientist, the concept, and the methods of the scientists were included in the plan. Table 3 summarizes the topics chosen by the pre-service teachers to prepare the history of science material.

Findings from reflective journals.

The first part of the reflective journal considers preservice teachers' ideas, feelings, and concerns about forthcoming instruction experiences. Considering the quotes and written statements of the participants, their purposes in using the HOS in instruction can be grouped under four domains of purposes, which are affective, conceptual, pedagogical, and epistemological. Details concerning the purposes of participants in using HOS in their instruction are presented in Table 4. These domains, presented in the left-hand column of the table, are: (1) the affective domain, which includes purposes for developing student attitudes; (2) the conceptual domain, which includes purposes for promoting the conceptual learning of content; (3) the epistemological domain, which includes purposes for promoting the appreciation of the aspects of science; and (4) the pedagogical domain, which includes purposes for developing the quality of teaching and learning.

Table 4. *Purposes of using the HOS*

Domain	Integrate to HOS to/ for	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**Total**
Affective	Humanize science & scientist		x	x	x	x	x		x	x		x				x	9
Conceptual	Teach scientific concepts	x		x	x												3
	Reinforce learning										x		x	x		x	4

Epistemological	Teach demarcation of science			x			x					x				x	4
	The tentative NOS		x				x			x		x			x	x	6
	Teach Science & society interaction			x			x					x				x	4
Pedagogical	Attract student attention to the topic	x		x		x		x		x	x	x	x	x			9
	Enhance teaching					x		x	x						x		4
Total		2	2	5	2	3	4	2	2	3	2	5	2	2	2	5	43

Pre-service teachers used the HOS for affective purposes at the first step. Humanizing science and scientists was the most common affective purpose of the preservice teachers. For instance, P11 states in his journal that including the life of Linnaeus and the struggles through his life during his studies in the lessons can help students to believe in themselves to become a scientist in the future and gain self-confidence.

"... my first priority is to attract students' interest in scientific world. To show that people who had great contributions to science were not living lives different that theirs. It was such a little time but experiencing a research process will help them to empathize with scientists and develop their belief in achievement." (P11- Humanize science and scientist)

"... seeing people who come from lives like they have, I plan to ensure students think like a scientist and to show that it is possible to become a scientist... and I plan to make students prioritize the curiosity and get into the habit of observing goings-on around them" (P9 - Humanize science and scientist).

As seen in the quotes, preservice teachers took on the view that living similar processes, making familiar experiments, or finding familiar points in scientists' stories would help students empathize with scientists. Another purposed of the use of the HOS was to attracting students' interest in the topic. It was observed that teachers who purposed drawing attention and attract interest to the subject matter at the beginning of the lesson used interesting stories from the HOS and planned this for the first ten minutes of the class period.

"Before the lesson, my aim for using history of science was to attract students' interest to the subject and make a review of the previous lesson." (P7 - Attract student attention to the topic).

"My aim… To help students build their own knowledge by themselves… and engage all students in classroom activities" (P4 - Attract student attention to the topic).

P7 uses the HOS for reviewing the lesson rather than teaching concepts. However, P5 plans her instruction by giving a role to historical information.

"I aim to make students have knowledge of progress in science. Starting with the first discoveries on the functions of the heart, I aim to attract to students' interest the lesson and continue the lesson…" (P5 - Attract student attention to the topic)

It seemed that preservice teachers tend to benefit from the HOS in pedagogical and affective domains rather than the conceptual domain. They planned to support and enrich teaching with the use of the HOS. Thus, they intended to attract students' interest, engage them in the lesson, and humanize the science. It was seen that among the conceptual purposes, the HOS was preferred to enrich the course content, and empower the teaching.

"I aim to teach concepts properly and to enrich instruction" (P12- Enhance teaching).

"My purpose is to support teaching and to enrich instruction. By this means ensuring students learn more" (P13- Enhance teaching).

"I have goals like helping students learn concepts and enriching instruction…" (P15- Enhance teaching).

The tentative nature of science is the most frequent concept revealed for epistemological purposes. For example, P11 planned half of her lesson by using the HOS and stated in her reflective journal that she emphasized the tentative and progressive nature of science.

"Linking the instruction with historical process, I think it can ensure students can observe the progress in science in every level and this can help students understand that science [scientific knowledge] can change… I will make them synthesize [the knowledge] by linking their work with Linnaeus's work. The aim here is to help them get well-structured knowledge while learning by doing and experiencing" (P11- The tentative NOS).

It could be argued that P11 focused on purposes that address the epistemological nature of science, and those helped students feel like scientists by familiarizing students with scientists. Another interesting finding was that preservice teachers who had teaching experiences could use the HOS for multiple purposes (P3, P6, and P11).

Concerns

Preservice teachers' concerns about the process of instruction were revealed in the first part of the reflective journals. These concerns are categorized by the expectations of students and lack of experience as presented in Table 5.

The primary concern of preservice teachers was that students' expectations and readiness may not be aligned with an instruction based on the HOS and therefore they think they may have difficulties in attracting students' interest in the lesson (15/9). For example, P11 expressed her concern as:

> *"I observe that since the first (academic) period which I start teaching students are not familiar with instructional approaches other than traditional didactic narrative activities. That's why I am worried about" (P5 - Expectation of students).*

On the other hand, P5 stated that he preferred to use the HOS as additional information and listening activity since he thought that students may have difficulties in question–answer activities based on the HOS.

Table 5. *Preservice teachers' worries about the process of instruction*

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Concerns	Expectation of students	x	x		x	x		x	x			x		x		x	9
	Lack of experience		x							x				x	x		4

> *"I am partially worried that the students' interest in the approach is insufficient due to the fact that the courses are not taught in this format and that I will not be able to get answers to my questions. Therefore, I think students will be more listening-oriented, so I planned it in reading." (P5- Expectation of students)*

In Turkey students have to take a national exam for university entrance therefore practices for multiple-choice tests are frequently preferred in the last grades. This habit of students prevents other instructional methods which preservice teachers were concerned about.

> *"What I worry is that students listen to lesson with in the concern of national university exams. At that point I think that if I teach concepts by using history of science students will view lesson useless." (P9- Expectation of students)*

Another concern related to code was preservice teachers' lack of experience. They defined HOS as a new kind of concept and style of teaching, so they felt they lacked experience in the use of HOS in teaching practice. As P13 expressed they planned not to get into uncharted waters (15/4)

"I am afraid that the lesson will be monotonous because I do not have enough experience, and this is a new style – I am afraid of not being able to attract the attention of student. – compared to being a teacher who just lectures, narrates because I cannot attract the attention of the students." (P13 – Lack of experience).

Experiences During the Teaching Practice

The featured findings as a result of the analysis of the second part of the reflective journals are teachers' decisions during the teaching practice and their interactions with students.

Student engagement

Preservice teachers frequently mentioned moments from their interactions with students during the instruction. Findings show that preservice teachers observed students' gestures, facial expressions, and attitudes during their use of the HOS in their instruction. Regarding preservice teachers' quotes, it is understood that the use of the HOS in instruction developed curiosity among students since students ask more questions about the given information, show interest, astonishment, and enthusiasm.

"Students' reactions to the [history of science] information that I gave were pretty good. The images and shapes about my narration were effective in understanding the lesson and asking to speak in class. They expressed astonishments with facial expressions and some voices while listening to the stories. The history of science was effective in their engagement in lesson" (P4)

It was observed that the preservice teachers, who were worried that the lesson would be monotonous because it would be a different environment than the expectations of the students, increased their confidence in themselves and the teaching plan they prepared after the positive student reactions. For example, P15 stated that she had the opposite experience while she was concerned that students would not be included in the lesson.

"More students than I expected asked to talk about their reasoning. With the interesting stories, students started to listen to me more carefully. When I said that each of them was a candidate to be a scientist, they started to ask more questions and tried to prove their arguments to their classmates" (P15).

Likewise, P7 expressed that, students were interested more than she expected and that made her happy about that.

"When I interact with students, I realized that they also want to engage in the lesson and the lesson attracts their interest. The thinking expression on students' faces was really worth seeing" (P7).

Particularly, preservice teachers who did not have teaching experience expressed their concerns about integrating the HOS into the lesson. However, they also expressed that the unexpected interest of students made the lesson enjoyable.

"Unexpected questions have come. Although the class was over some students came to ask more questions. Their enthusiasm for the lesson and continuous questioning stressed me out but also made me feel good." (P2)

"As they gave answers to my questions I felt better. How they carefully followed the lesson made me happy. They especially listened carefully to the part about the history of science." (P6)

"Students' desire to make a speech and present their views during the question-answer and discussion periods led the lesson to flow pleasurably" (P3)

Decisions

Preservice teachers' experiences during the enactment of their plans in the classroom revealed the subtheme "decisions" with codes "decisions concerning time management" and "decisions concerning interaction" that cover quotes about how they transform their plans concerning the instructional environment. Preservice teachers' quotes on their decisions on- scheduling the lesson plan during the instruction were coded as "Decisions concerning time management".

Considering the theme during the instruction, findings showed that preservice teachers had interactive decisions as a result of students' reactions, questions, or remarks. Their quotes on active decision-making processes during the instruction may give a clue about how they could master using the HOS in their instruction. One of the decisions they made was on time management. As Duschl says, "The enemy in the classroom is time."

"In total, I did not do anything outside of my plan. However, my lesson was finished 10 - 15 minutes earlier than I planned. I wanted to use that time efficiently, so I had a question-answer activity with students. The question-answer activity was in my plan, but it was in lesson flow. So, since I had free time, I decided to get this part to the end of the lesson." (P2- Decisions concerning time management).

Therefore, preservice teachers encountered the enemy in their instruction and they used the HOS. Their decisions were linked closely to students' interests since their participation in the activities determined the duration.

"... I did not overstep my lesson plan. Only I was quick in the subject of cloning the Dolly... Besides this, I completed the lesson 5 minutes earlier than I planned. For this reason, we talked with students about things they are curious about" (P11- Decisions concerning time management).

Some more time left than preservice teachers planned because students were not interested in the subject as they expected. Therefore, they needed to add some extra activities to complete the class hour.

[In the first classroom] It was good in the question-answer part, they asked so many questions, so I extended the time for this part. In another class, I changed my plan concerning the time. However, the lesson was completed earlier than I planned. I think that was because of less interest and short answers to the questions (P3- Decisions concerning time management).

Preservice teachers preferred question-answer activities, which got students more interested in filling in their free time. Students were eager to ask questions and talk about the content within the frame of the HOS in this period. Preservice teachers were capable of making decisions and managing processes. Quotes presenting preservice teachers' decisions on their lesson plans concerning their interaction with students were coded as decisions concerning interaction. It was observed that pre-service teachers stated that they made changes during the teaching practice in their previous decisions regarding the use of HOS according to the current needs and situation of the classroom.

As seen in Table 3, P1 plans to use the HOS with conceptual aims but on the other hand, he also has a concern about students' readiness. However, during the teaching practice the interest of students, and their questions on the subject led him to verify his aims by addressing science and society interaction through the stories from the HOS.

The points that I was interested in also attracted students' interest but when I was preparing the instruction plan, I had focused on more concrete concepts and aims but I decided to move on with respect to students' answers to the questions. I talked about Avicenna, and I completed the class time. (Decision concerning interaction).

The positive feedback from students helped the preservice teacher to relieve and therefore carry out the lesson easily.

They shape the process. When I got the unexpected positive reaction, to sustain the lesson flow I took the different dimensions of the science. (P4 Decision concerning interaction).

Another outstanding finding related to the teaching practice process was the differences between preservice teachers who were teaching for the first time (e.g.P2) and those (e.g. P3) who had more teaching experiences.

As if there are two distinct lessons in my instruction but as a whole, I tried to combine them. The engagement of students was more than I expected. I encountered various questions. I could not understand how I could do that, but I was able to answer all of them. (P2 Decision concerning interaction).

I had no difficulties because I used the history of science as a tool. I did not make a statement that would make a difference, as we will teach the lesson with the history of science today, and everything was in its normal course. Class participation was high. (P3- Decision concerning interaction)

Experiences after the teaching practice

After instruction, experiences that cover self-evaluations of preservice teachers concerning their instruction and related findings are shown in Table 6. While preservice teachers' quotes that define their feeling about being sufficient in using the HOS in their instruction were gathered under the theme of "strengths", the quotations about their inefficiencies in using HOS in the classroom were grouped under the theme of "weaknesses".

Table 6. *Preservice teachers' concerning after the instruction worries about the process of instruction*

		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**Total**
Strengths	Professional pleasure	x	x		x					x		x				x	6
	Professional development			x	x	x	x				x		x	x	x	x	9
	Effective lesson	x							x	x		x		x	x		5
Weaknesses	Lack of HOS knowledge	x		x			x		x			x					4
	Lack of pedagogy		x				x	x					x				4
	Linking between the HOS and content knowledge		x	x		x		x	x		x			x	x	x	7

Weaknesses

Preservice teachers did not utilize the theoretical information on the use of HOS that was included in the syllabus; rather they preferred to narrate by using stories. The third section of the reflective journals that they evaluated the teaching practice experience showed that they had difficulties in combining the content knowledge and the knowledge on the HOS (6/15), they felt inadequate about their knowledge of the HOS (4/15), and they had difficulties in pedagogical (3/15).

"In the classroom, in which I gave the lesson, they gave answers and they discussed. But a contrary situation also could happen. I need extra information to engage students in the lesson." (P7- Lack of pedagogy)

"In this experience, I just focused on one concept so I could link the history of science information and the content knowledge. However, I have to be ready regarding not only content knowledge but also historical concepts for curriculum content" (P5- Lack of HOS knowledge)

Findings revealed that, although they felt sufficient on the subject that they had prepared for, for the rest of the curriculum, preservice teachers demanded detailed information or readings that helped them in integrating the HOS into the content knowledge namely a material pool that covers needed sources.

"I can find the information on the history of science, but we are teachers. There need to be sources that show us how to combine that information with content knowledge. It would relieve me if I had sample materials like photos, videos, or documentaries which I could choose apt to class time". (P3- Linking information the HOS and content knowledge)

Strengths

Table five shows that preservice teachers feel more self-confident and developed professionally after the theoretical instructions and their own teaching practice experience.

"I would have had difficulties if I had not taken a history of science course, but this experience gave me self-confidence. In my next practice, I can try other technics like creative drama or creative writing. I could not integrate many things that I learned in my history of science course into the classroom, I can use what I learned more actively in my next experience" (P13- Professional development).

"I relaxed a little and now I would encourage the students by making them curious about the paintings, artefacts, and life stories by making them more active in the lesson" (P3- Effective lesson).

Earlier I had fears and concerns. But after lecturing, I believed I could do it. I want to use the HOS for the sociocultural level in my next experience (P11- Professional pleasure).

Preservice teachers would like to use various techniques that they did not use in their first experience and they stated that they would like to vary not only the techniques but also the purposes of the use of HOS in their lessons. Concerning their various concerns, the preservice teachers who focus on the purposes of interest or humanization stated that they would like to focus on science and society interaction and on teaching concepts by drawing parallels.

RESULT AND DISCUSSION

The use of HOS in science education dates back to the 1950s. National curricula, and international science education policies stress the importance and role of the HOS. Researchers underline the need for HOS in teacher education programs as the current study also supports. However, from the perspective of teachers who apply theories in reality there are still problems. As well as this study, previous studies focus on the problems or obstacles in using HOS in instruction. Still, teachers experience the same problems as the literature shows such as difficulty in adding historical information into existing programs (Stinner and Williams, 1998), lack of information or misuse of information (Jung, 2000 in Leite, 2002), linking HOS information with the content knowledge (Seker and Guney, 2012) although a specialized curriculum is used for them. In a recent study by Bakanay and Cakır (2022), participants used instructional curriculum materials based on HOS developed in conceptual, epistemological, and sociocultural contexts in real classroom environments. As a result of this study, it was reported that although materials were developed in-depth, participants were not ready to use the materials pedagogically, even after 2 years of practice.

Considering the findings on the purposes of the participants, it is clear that they approach the HOS in an affective domain. Their tendency is not toward conceptual or epistemological aspects of using the HOS. The reason for the affective use of the HOS can be linked to their obstacles and interpreted as the lack of knowledge of the HOS since they are not well supported to discuss scientific concepts conceptually and epistemologically within the frame of the HOS.

After the instruction, preservice teachers stressed that the HOS facilitates classroom management, attracting interest and achieving an understanding of the aspects of the NOS. It was underlined that the HOS provided a fluent lesson by attracting the interest of students better classroom management and fulfilling the objectives of the lesson. Therefore, they would prefer to use the HOS in their future lessons. Considering the young and inexperienced participants, the effect of the

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HOS on classroom management by attracting attention and interest and encouraging science, using the HOS in the lesson can be a tool for facilitating in-class interaction. Studies that use the history of science within the concept of interest (e.g. Seker and Welsh, 2006; Teller and Stinner, 2005; Wieder, 2006) states the positive outcomes of using the history of science in science lessons in students' interest and motivation. Aligned with the literature, in the current study, preservice teachers shared their experiences of attracting interest and building up an in-class interaction as a result of their use of the history of science in their instruction.

Remillard (2005) states that teachers have to make changes throughout lessons with respect to students' expectations or needs to adapt the instruction to fulfil the needs of students (Brown and Edelson, 2003). That means that teachers should actively make decisions during their instruction which Duschl (1987) focuses on. The current study focused on preservice teachers' decisions concerning time management and interaction. Starting with the time management decisions, findings showed that preservice teachers needed to rearrange their plans since they had more time than planned. In contrast to the literature that focuses on teachers who say, "I do not have enough time" (Collinson and Cook, 2001; Hargreaves, 1990 in Watts and Castle, 1993), the participants of the current study made their decisions because of the time left after completing their plan. Although that could be discussed within the experience level of the teachers, according to the mentioned literature on time management it should not be forgotten that teachers deal with many things at the same time, aim to complete processes, have a high sensitivity to context, and have a sense of time towards people and relationships (Hargreaves, 1990 in Watts and Castle, 1993).

In parallel to this basis, the participants made decisions concerning the interaction with students. Findings showed that students' interests, reactions, and questions on the concept directed preservice teachers to rearrange their plans. Although it is nice to see that preservice teachers could integrate communication by using scientific knowledge which is an important dimension of science education (Chan, 2011) by asking questions and making classroom discussions (Rivard and Straw, 2000), findings on their experiences after instruction reveals the need for pedagogical and conceptual support concerning the history of science. Findings showed that participants needed to add the HOS knowledge to their content knowledge, but they felt doubtful considering the students' readiness, their efficiency in integrating the content knowledge, and the HOS knowledge.

To take action during the lesson they need to feel strong pedagogically and conceptually. First of all, the content of the HOS lessons in universities should be expanded to the conceptual and epistemological bases for preservice teachers to understand and internalize the HOS context. Courses on the content knowledge of the field should cover the history of the concepts by focusing on how the concepts were developed throughout the time. Courses on pedagogical practices should include the methods and strategies of the use of alternative pieces of knowledge such as the HOS.

Applying a curriculum has three main bases, which are curriculum, teacher and students, and teachers are the bridges between the curriculum and the students (Remillard, 2005). How a weak bridge fails in connecting the landmasses insufficient teachers would also fail to enact curriculum and to benefit students. Consequently, teacher education programs should consider preservice teachers' needs and take concrete steps to support teachers' self-efficacy for using HOS in instruction. Designing teacher education programs considering the concerns, obstacles, and weaknesses of preservice teachers' practices may help in more efficient use of the HOS in science lessons and help obtain the possible outcomes of the use of the HOS that are mentioned in the literature.

Conflict of Interest

There is no personal or financial conflict of interest between the author and participants of the article within the scope of the study.

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